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Title: COVID-19 Modeling for Pandemic Response

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GLOBAL DISEASE MODELING & FORECASTING CENTER

COVID-19 Modeling for Pandemic Response

Los Alamos NATIONAL LABORATORY EST. 1943

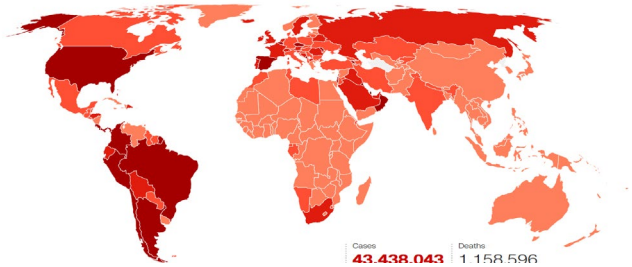
Kirsten Taylor-McCabe
Global Security Program Office
November 3, 2020

NNSA National Nuclear Security Administration

Managed by Triad National Security, LLC for the U.S. Department of Energy's NNSA

Some key facts about the COVID-19 Pandemic

- The Coronavirus disease 2019 (COVID-19) is caused by SARS-CoV-2 and is spreading from person to person mainly through respiratory droplets, aerosols and fomites.
- Spread is more likely when people are in close contact with one another.
- Symptoms may appear 2-14 days after exposure to the virus.
- U.S. number of known cases is doubling about **every three months**.
- ***This is a new virus and we are still learning.***

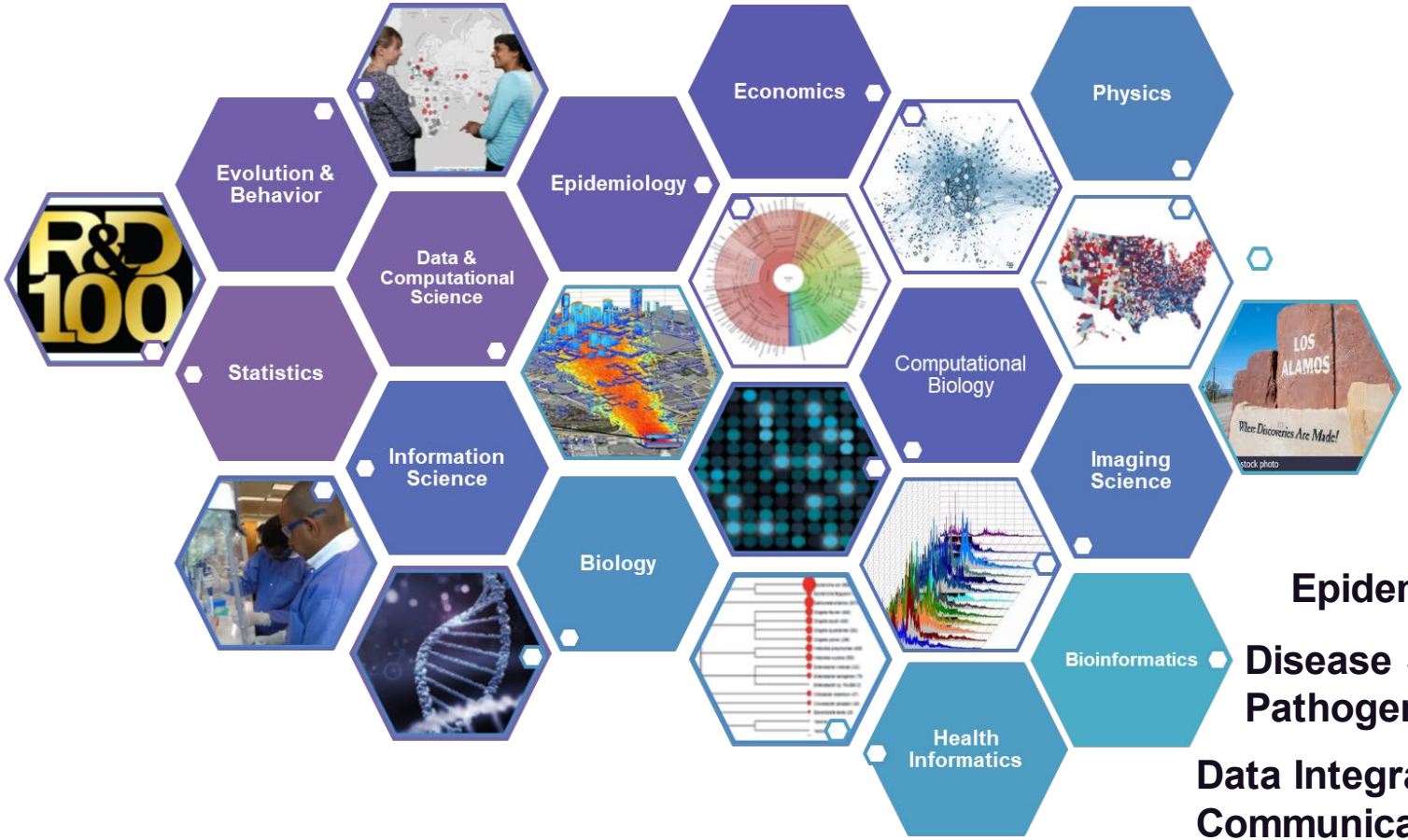


What we need to know

. …science for decision making

Scientist at LANL are involved in the global effort to understand this outbreak.

LANLs Core Team Disciplines



Epidemiological Modeling

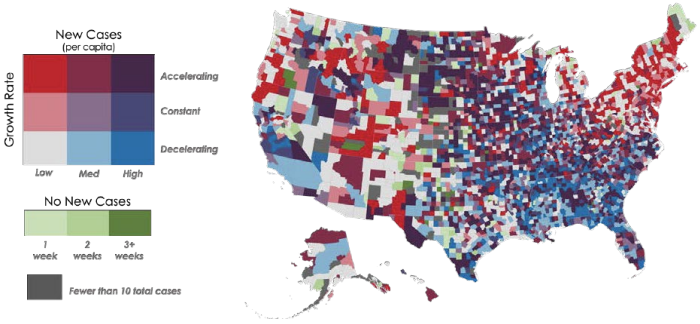
Disease Surveillance and Pathogenesis

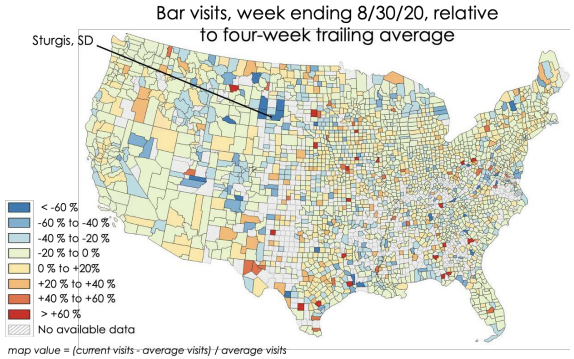
Data Integration and Risk Communication

NVBL

Joint DOE Effort for Pandemic Modeling and Analysis Overview

ORNL, ANL, SNL, LANL





- Recognized potentially very high values of R_eff very early in pandemic.
- Careful modeling on NY, Seattle, Wuhan, and Italy enabled determinants of force of infection to be dis-entangled and thus translated from scenario to scenario.
- Provided early posting of statistical models, translated to hospital and ICU loadings.
- Provided detailed comparisons of impact of bars and schools re-opening on COVID spread.
- Recognition of Descartes Labs cell phone data in capturing by-county variation in R_eff.
- Quantified contact tracing as 40-60% effective when 300 tracers per 2M population were deployed, as independent mitigation to masks / social distancing / closures.
- Developed systems-engineering model relating testing turnaround time, sensitivity & specificity, contact tracing & isolation to consequence.

McMahon & Team

Modeling provides a framework to evaluate forecasts, potential actions, and specific scenarios

Decision Makers
- Situational assessment
- Scenarios / options
- Metrics evaluations
- Confidence assessment

Data
- Availability
- Quality/Key inputs
- Assumptions
- Model performance

MODELING

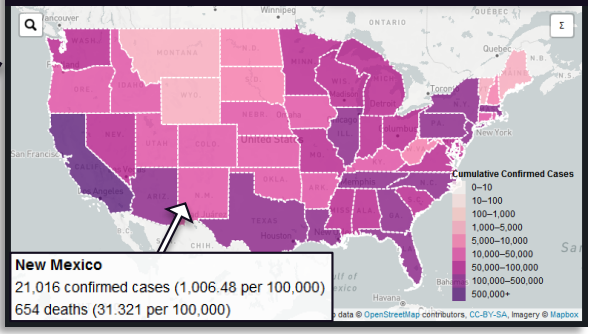
Forecasts up to 6 weeks
- Statistical approach
- Publicly available
- Originally validated with influenza

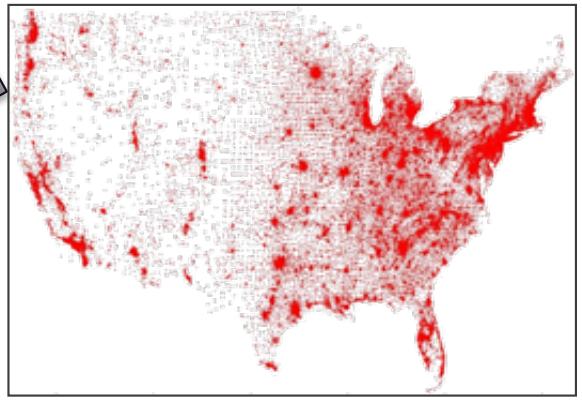
Simulation of different scenarios
- More computing required
- Designed for scenario
- Two LANL approaches
  - EpiGrid: Geographically-segregated SEIR+
  - EpiCast: Agent-based

Forecast

Prediction

Cases and Deaths Forecasts
Based on data as of 2020-08-02
https://covid-19.bsvgateway.org/

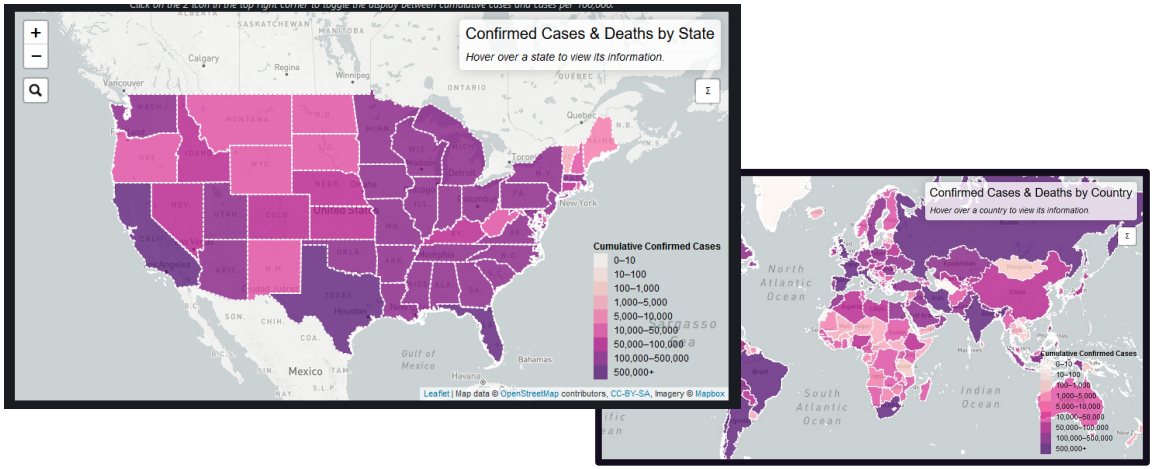


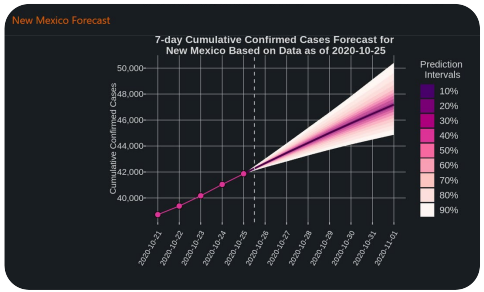


- Outbreak surveillance, Hot Spots, Mobility factors/impacts, Transmission links, School re-opening, Non-congregate housing needs, Short-term hospital resource needs, vaccine distribution strategies, impacts of mitigations/contact tracing and more.

Models Improve Understanding and Support Pandemic Response Decisions: Forecasting

COVID-19 Cases and Deaths Forecasts





6-Week Forecast of Confirmed Cases for New Mexico Based on Data as of 2020-10-25

Week	Best Case (5th Percentile)	Middle Case (50th Percentile)	Worst Case (95th Percentile)^
2020-10-25		41,863*	
2020-11-01	44,864	47,190	50,410
2020-11-08	46,922	51,939	59,788
2020-11-15	48,553	56,072	69,805
2020-11-22	49,656	59,651	79,804
2020-11-29	50,470	62,610	89,660
2020-12-06	51,107	65,313	99,499

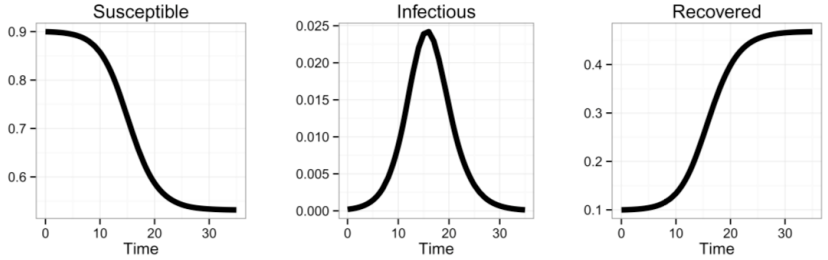
*Last reported confirmed cases count
^Closest-matching scenario

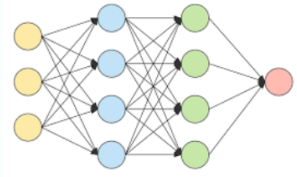
- Forecasts up to six weeks ahead for all US states and many countries. Forecasts are probabilistic, providing a range of possible future outbreak trajectories.
- CDC-cited model
- New Mexico Department of Health Operational Support
- https://covid-19.bsvgateway.org

Osthus & Team

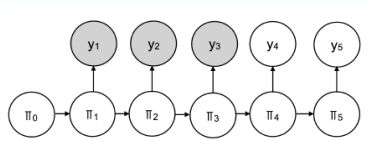
Models Improve Understanding and Support Pandemic Response Decisions: Forecasting

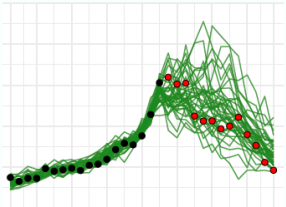
- **Infectious disease forecasting that blends the structure of epidemiological models with the flexibility of machine learning**



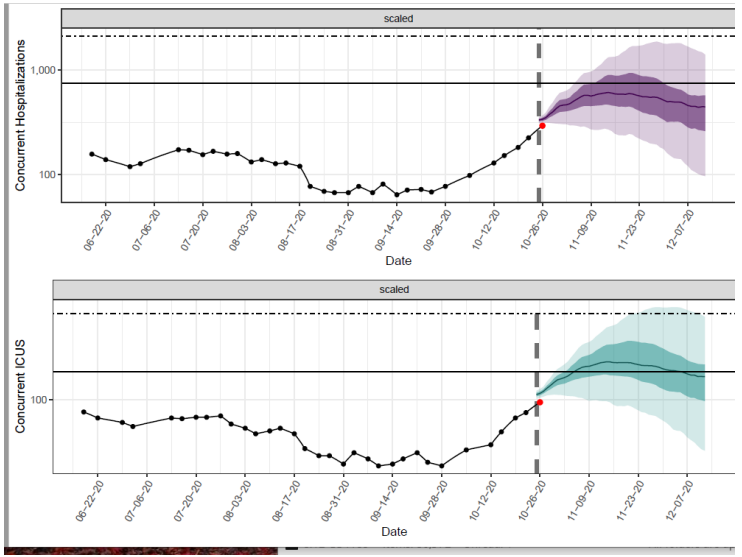


$$\hat{y} = f(X, \beta)$$





- **Model has been successfully applied to real-time influenza and COVID-19 forecasting. Can be extended to many diseases and geographies.**

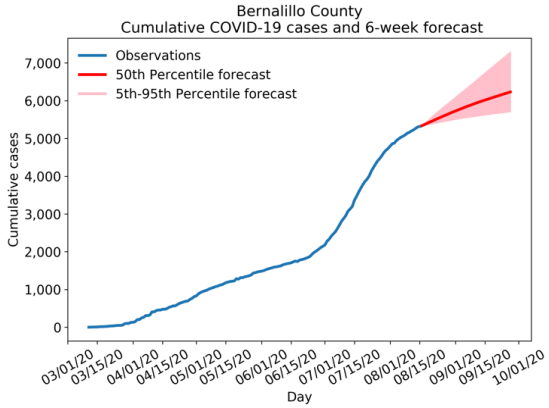


So what?

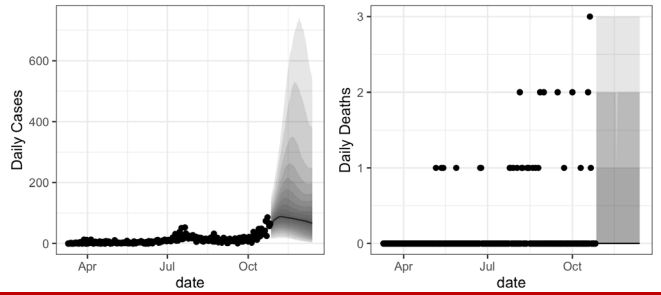
We are on track to *exceed ICU beds by November 8.* This is using the updated LANL forecasting model COFFEE.

Support Pandemic Response Decision

Non-Congregate Shelter Forecast Estimates to facilitate planning action.



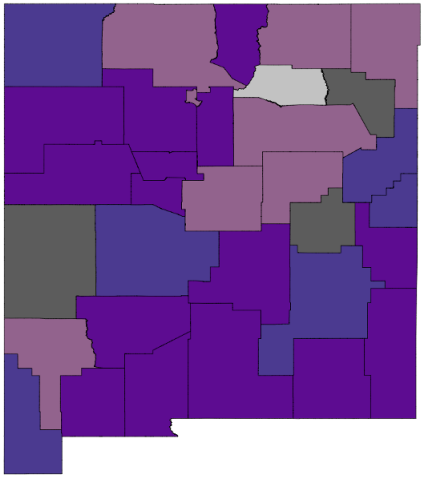
Health Region - NM Northeast Region

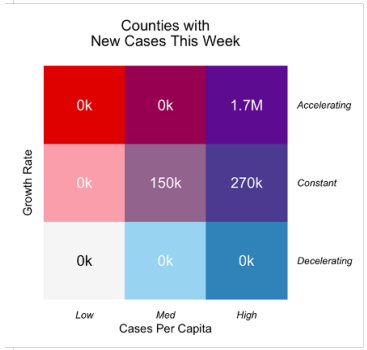


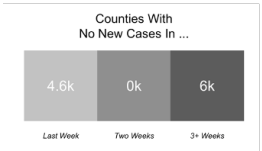
The daily number of cases is expected to range between 80 and 90 for the middle case scenario in the next few weeks

COVID-19 across New Mexico

A 7-day moving window comparison
Oct 26, 2020





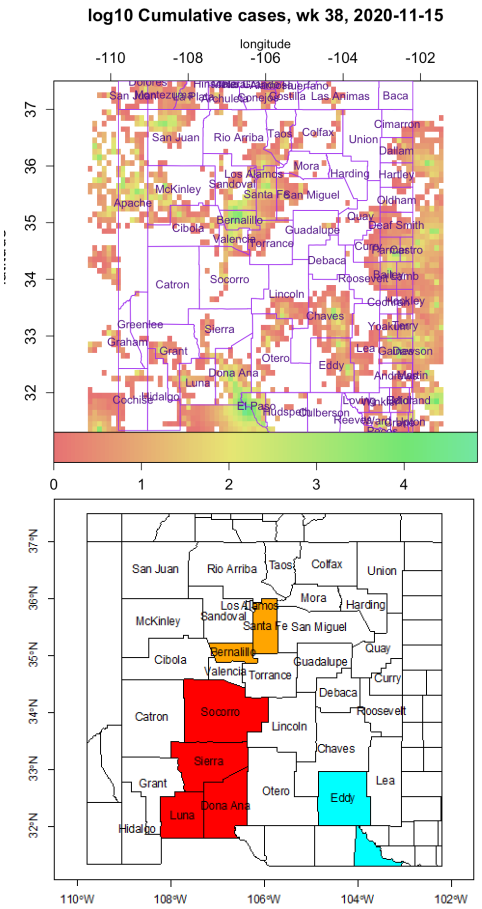


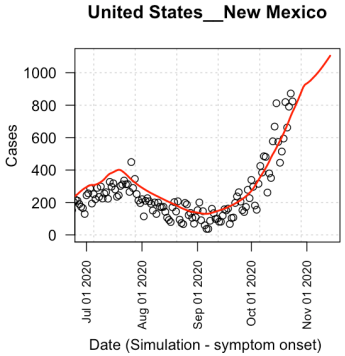
So what?

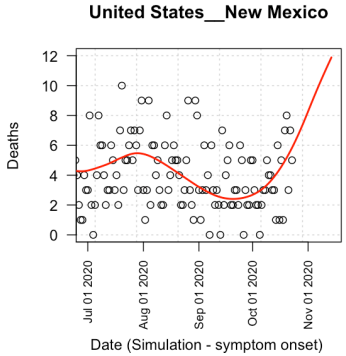
- **MOST New Mexicans live in a county with currently accelerating growth and high per-capita case counts**
- **No counties are decelerating right now**

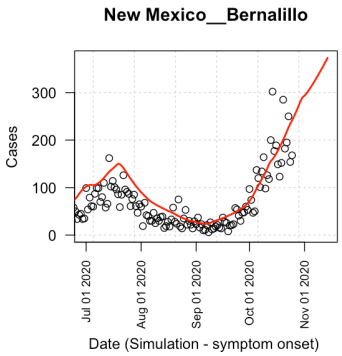
Manore, Del Valle & Team

Impacts of Assumptions and Interventions





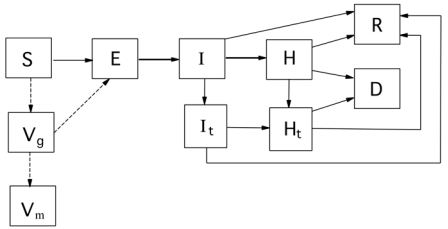




EpiGrid

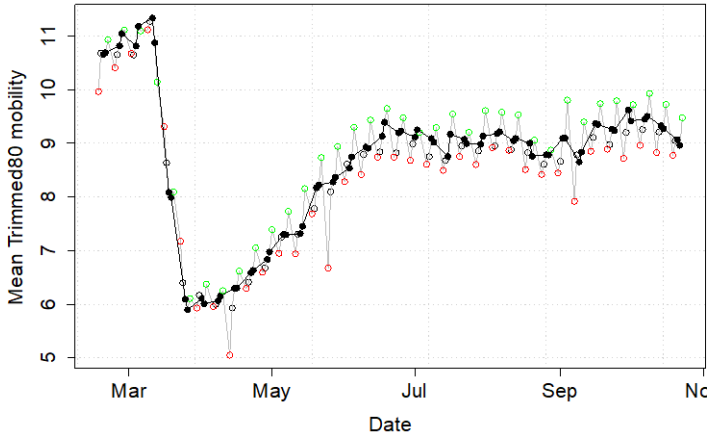
Readily parameterized medium-grained epidemiological model that puts mitigations on an equal footing with disease biology and epidemic spread.

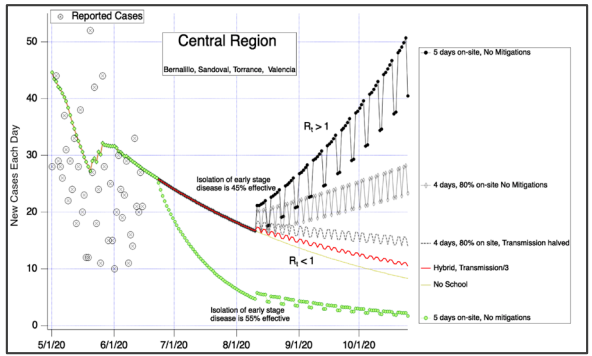
- Model is enabling timely and accurate decision support.
- Helps work through biology "vs." scenario analysis

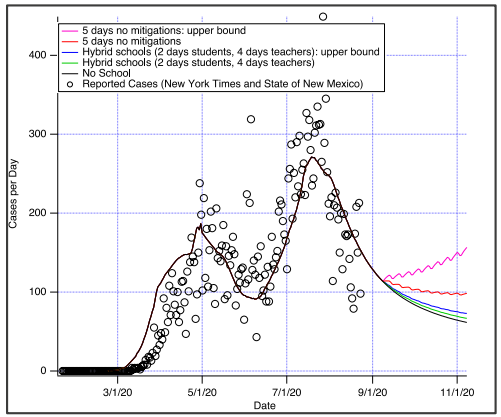


Fenimore, Mourant & Team

Impacts of Assumptions and Interventions





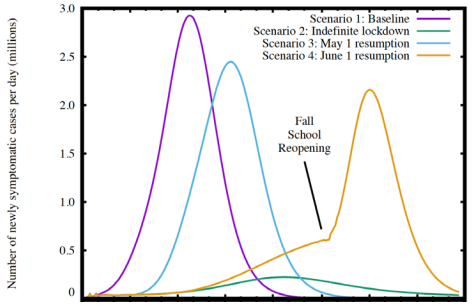


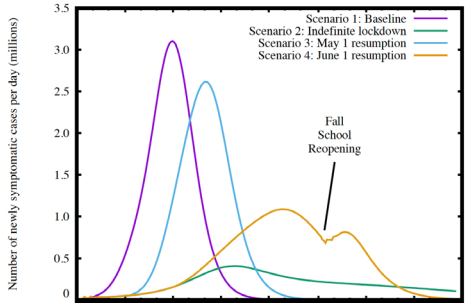
- Improving geographical situational awareness; treatment of geographical heterogeneity is improved by transport data.
- How do we plan ahead? Work with government to develop scenario parameterizations for necessary mitigation actions.

Improving disease emergence situational awareness and preparation.

https://cvmodeling.nmhealth.org/medical-advisory-team/modeling-updates/

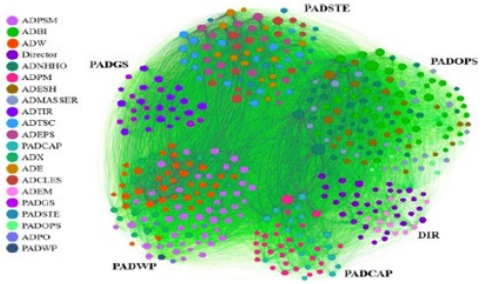
Impacts of Assumptions and Interventions



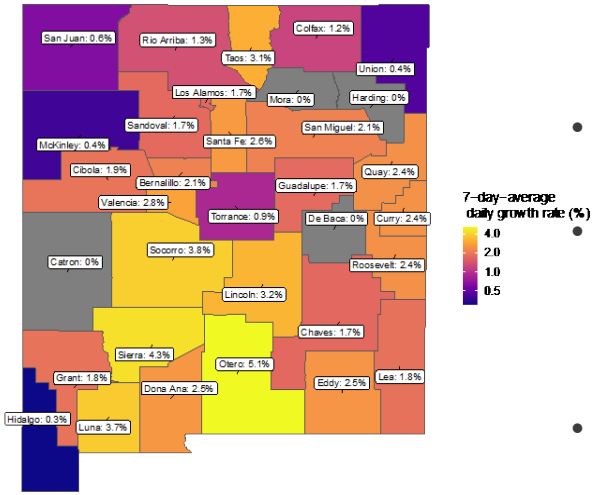


So what?

Relaxation of interventions can result in a second wave of infection



LANL-specific modeling support



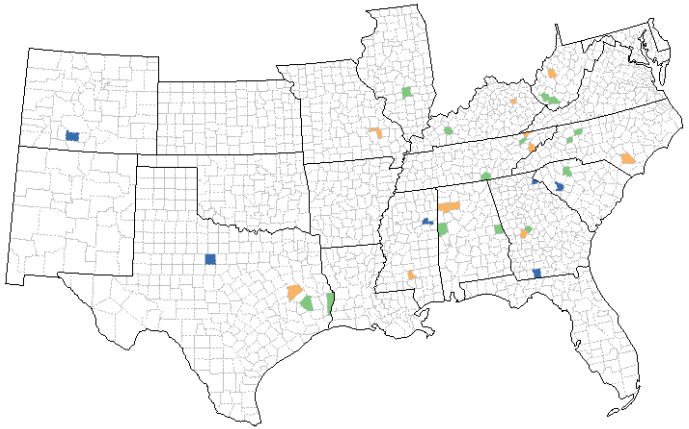
Del Valle, Germann, Manore & Team

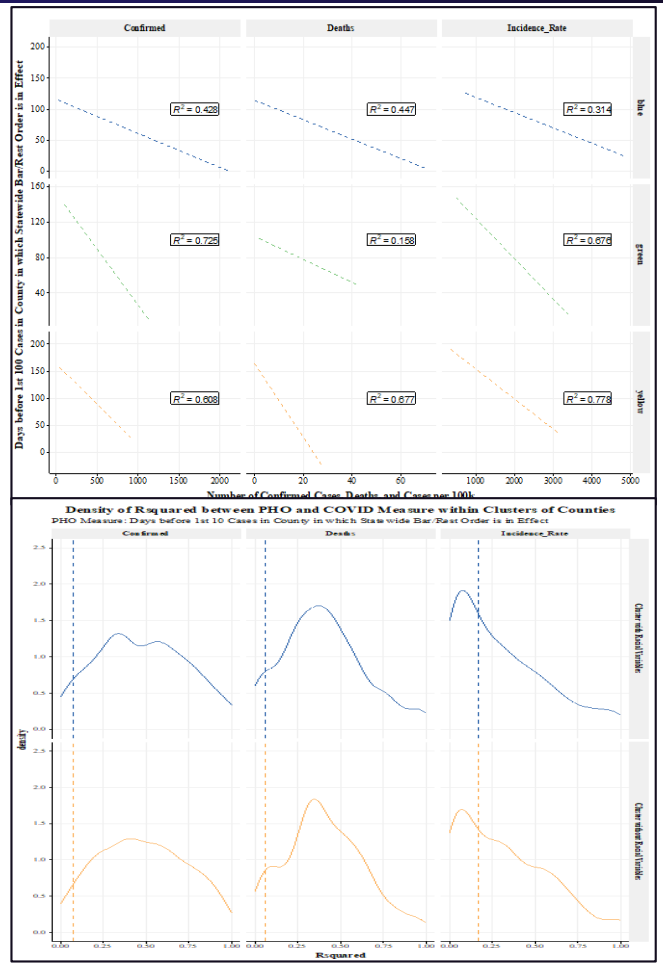
EpiCast

- A fine-grained hybrid-agent epidemic model with diurnal agent travel and contagion compartments that allow the analysis of the importance of contact-networks, travel, and detailed intervention strategies for the control of outbreaks and epidemics
- 2000-person communities in 65,433 census tracts
- Explicit model of geography, demographics (i.e., age), worker/household/school/ community contacts, and mitigations
- Captures workforce by 3-digit NAICS

Impacts of Assumptions and Interventions

Counties clustered based on similar income, population size, age, and education

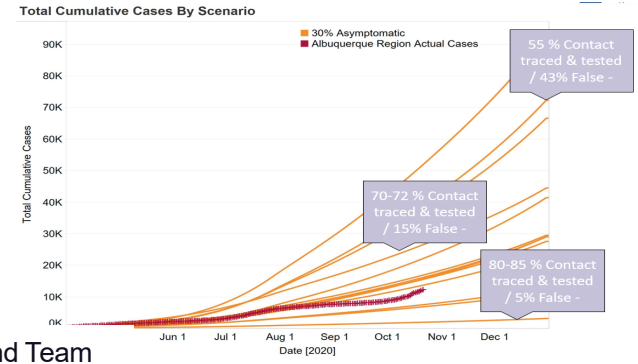




There is a correlation between cases and bar and restaurant public health orders – the number of cases increased as bar and restaurant orders were relaxed

Martinez, Manore, Germann, and Del Valle

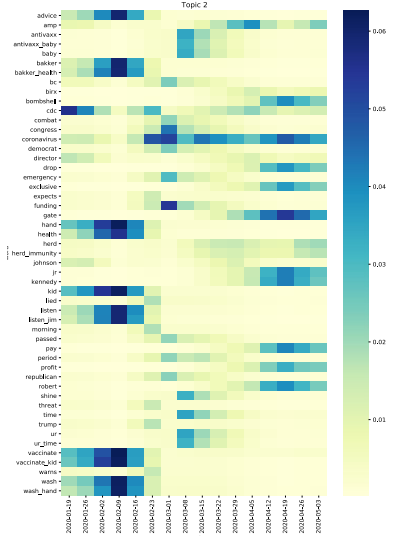
COVID-19 Studies on Drivers of Pandemic Outcomes

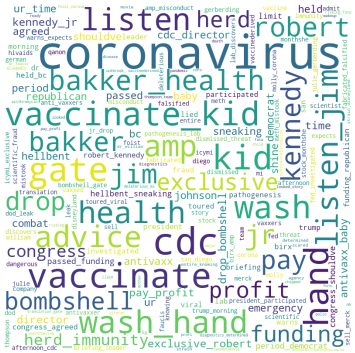


Fair and Team

Modeling epidemics for decision support with infrastructure analysis (MEDIAN)

- Understand interdependencies between critical infrastructures, contact tracing, testing and diagnostics to uncertainty in the primary drivers of pandemic outcomes and mitigation impacts
- Contact tracing and testing is vital but the acceleration of cases is still driven by isolation and quarantine.



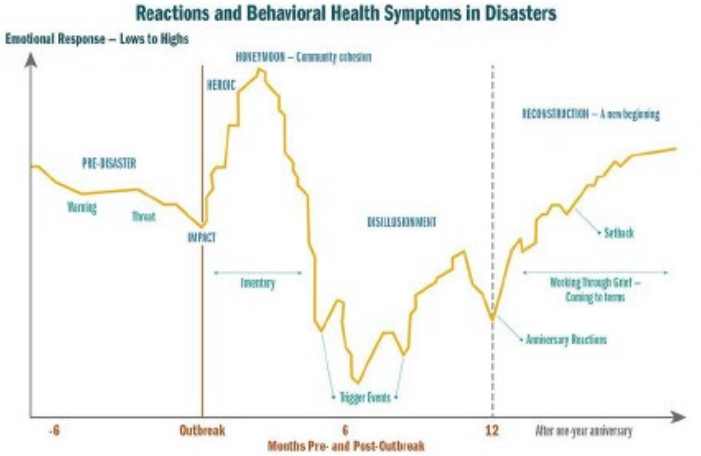


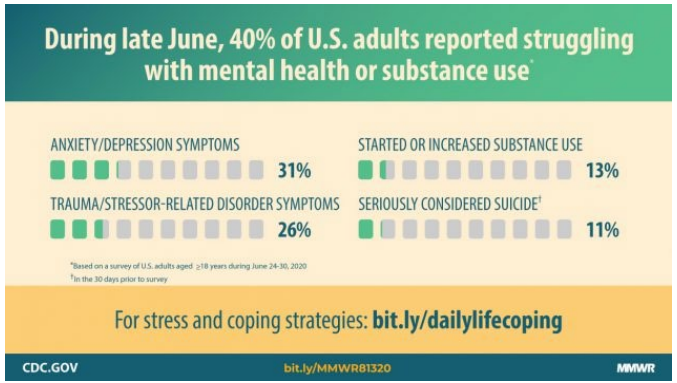
Daughton and Team

Mining Nontraditional Data (e.g., Google, Twitter) to Measure Human Behavior

- Analyze trends geospatially and over time using natural language processing (e.g., sentiment analysis, topic modeling) and machine learning
- Understand evolution of important words to observe important shifts (e.g., patterns in tweets suggesting vaccine adverse beliefs) that can inform communication strategies.

COVID-19 Impacts on Behavioral Health

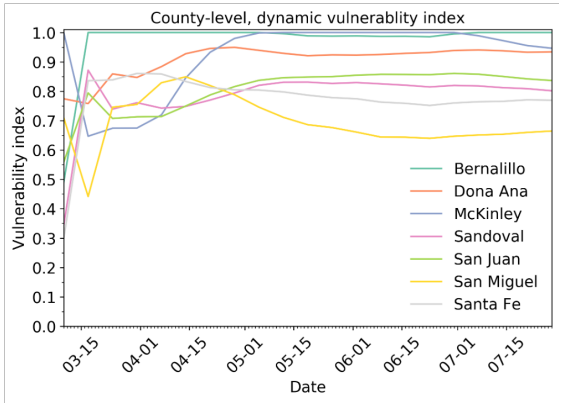




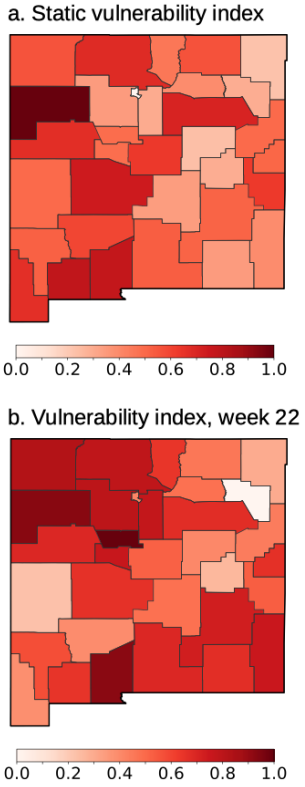
McMahon, Manore, Daughton and Team

National disasters such as pandemics impact mental and behavioral health, including depression, anxiety, domestic violence, and substance abuse.

These impacts often occur in phases (see top left).



We are analyzing state data about mental health along with socio-economic factors to estimate vulnerability and help determine future needs.



Vulnerability index based on socio-demographics, changing in time with COVID-19 cases

We are investing LDRD funds in research on COVID transmission and outbreaks in the state

Approach

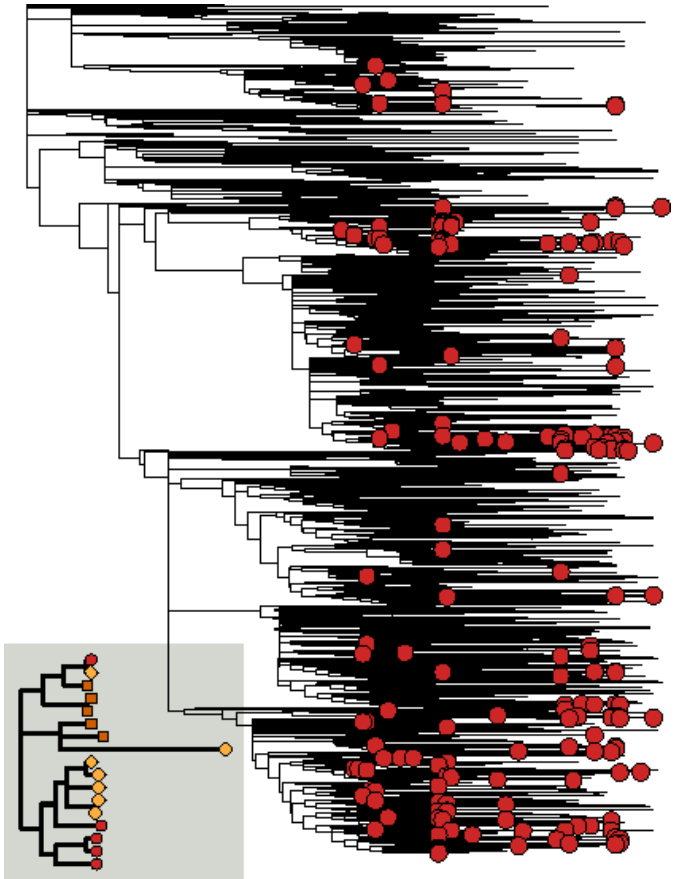
- SARS-CoV-2 mutations reflect a tree of relatedness among cases, and hence transmission links

Methods

- Tree-based analyses reveal when the virus moved into/out of NM, and hence NM transmission clusters

We have found we can:

- Identify many transmission links known to NMDOH
- Support transmission links suspected by NMDOH
- Suggest additional cases likely to be part of outbreaks
- Show that outbreaks often result from multiple introductions (rather than having a single source)

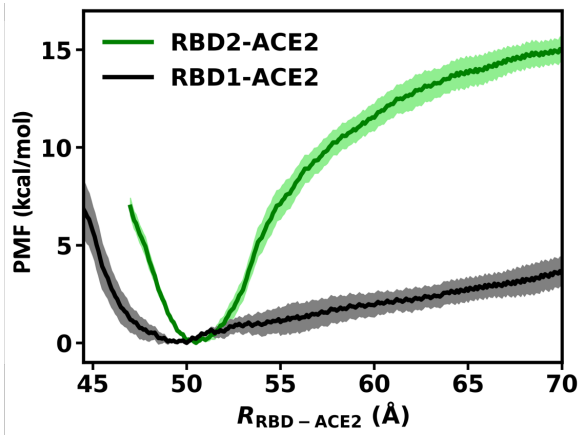


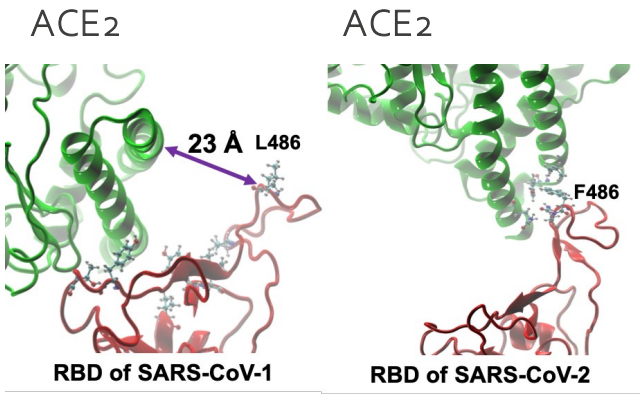
NM cases (red circles) are mixed among cases from elsewhere, showing many introductions of the virus into the state

Inset: Cluster sub-tree shows transmission link between two NMDOH-designated outbreaks

Goldberg and Team

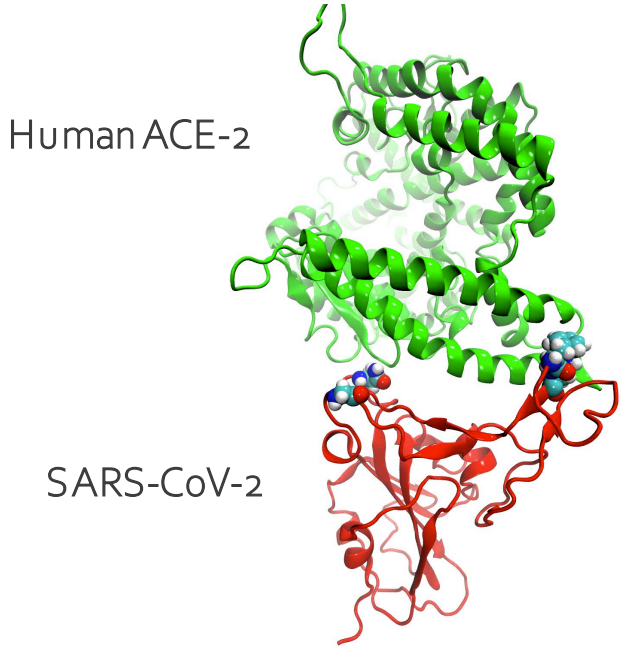
LANL High Performance Computing: Why is SARS-CoV-2 more invasive than SARS-CoV?





Ngo, Jha and Team

Forming a Tighter Grip
Revealed by extra long MD simulations



- The receptor binding domain of SARS-CoV-2 has evolved to have a stronger grip on Human receptors ACE2 than SARS-CoV.
- Loop with F486 on CoV-2 forms a sticky anchor and maintains interaction with ACE-2
- Loop with L486 on CoV dislodges easily

The D614G mutation

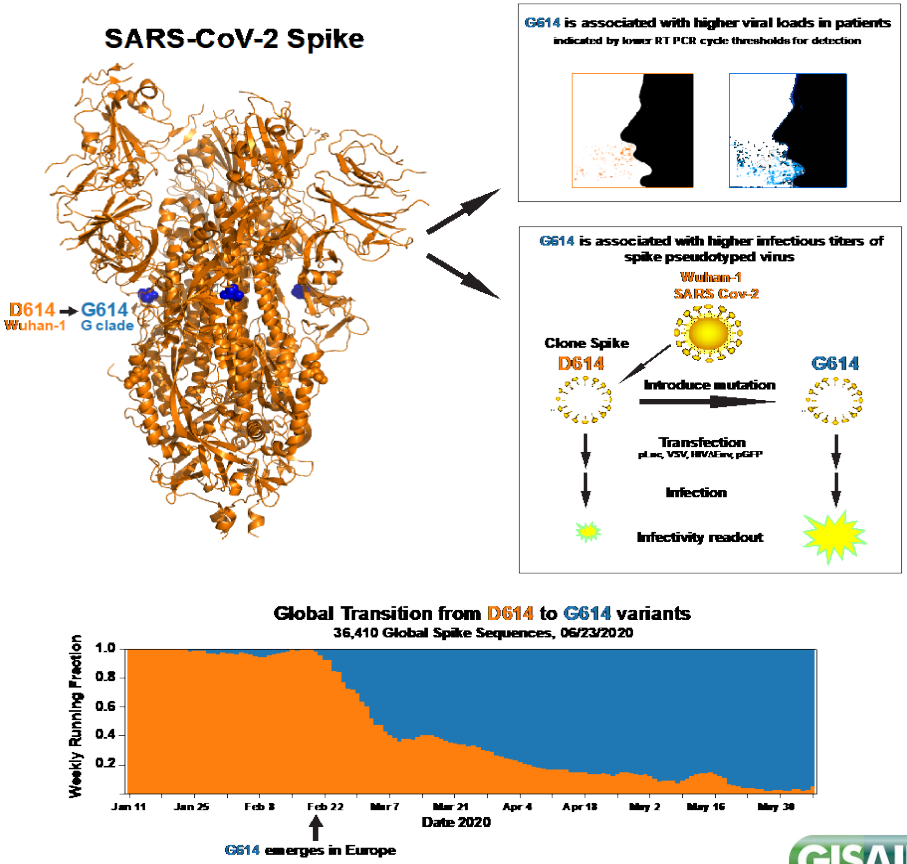
SARS-CoV-2 Spike is the protein that mediates virus entry into cells and it's the prime target of COVID vaccines.

A single mutation in Spike, D614 to G614, has become the dominant form of the virus in the pandemic.

The G614 form is more infectious.

The G614 form is associated with higher levels of viral RNA in the upper respiratory tract of infected people.

The G614 was not associated with increased hospitalization.

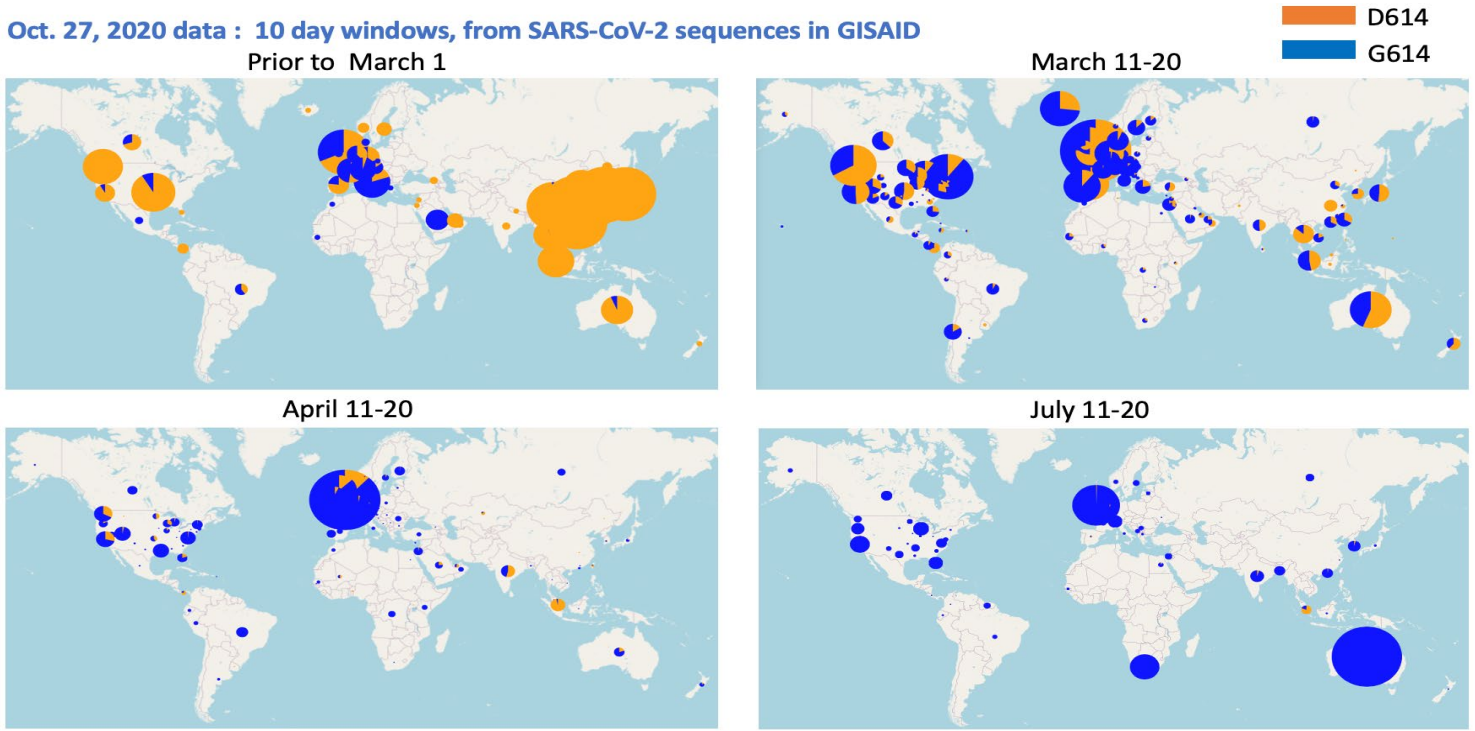


Tracking Changes in SARS-CoV-2 Spike: Evidence that D614G Increases Infectivity of the COVID-19 Virus.
Korber B, Cell. 2020 Aug 20;182(4):812-827.e19.

Korber and Team

The D614G mutation

By mid-summer 2020, the G614 form had become the globally dominant form of the virus



LANL built computation tools to geographically/temporally track mutations in the COVID-19 pandemic

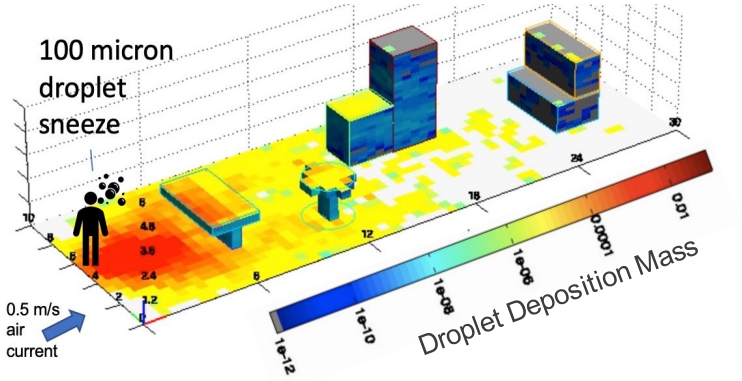
cov.lanl.gov

Fueled by GISAID

Virus-Containing Droplet Plume Modeling

DOE Office of Science: Viral Fate & Transport for Covid-19

How far can virus-filled droplets travel?

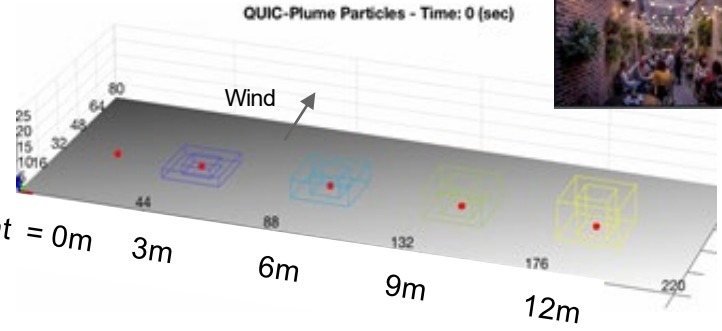


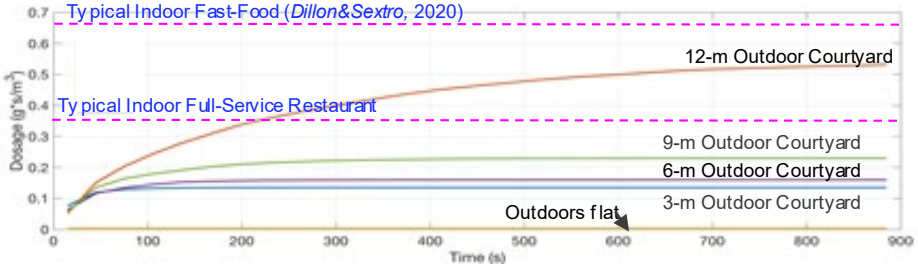
- LANL's QUIC plume model is used to account for dispersion and deposition of droplets accounting for air currents, turbulence, gravitational settling & droplet evaporation.
- With a 0.5 m/s air current and medium to low humidity, 100-um droplets can travel **10+ meters** before settling out onto surfaces

Brown and Team

Is outdoor dining safe?

1-person breathing in center of each courtyard

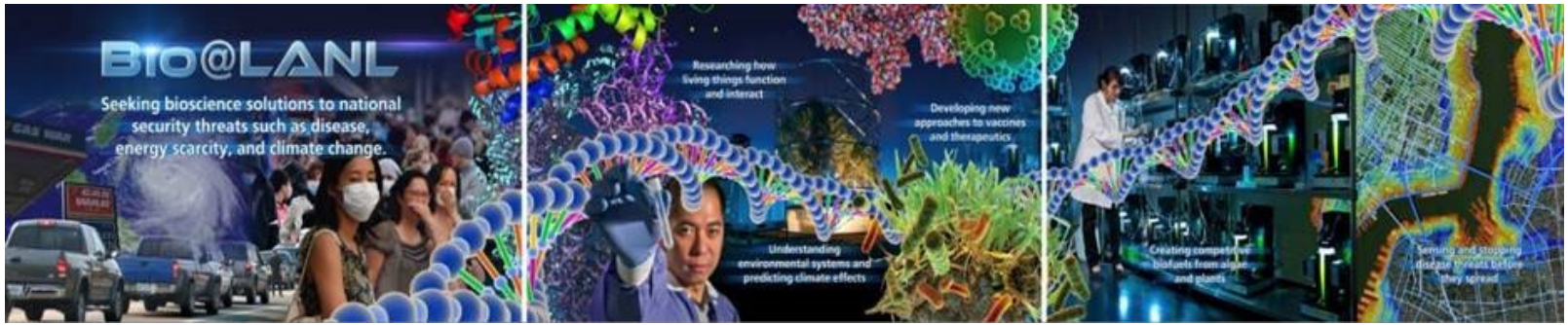


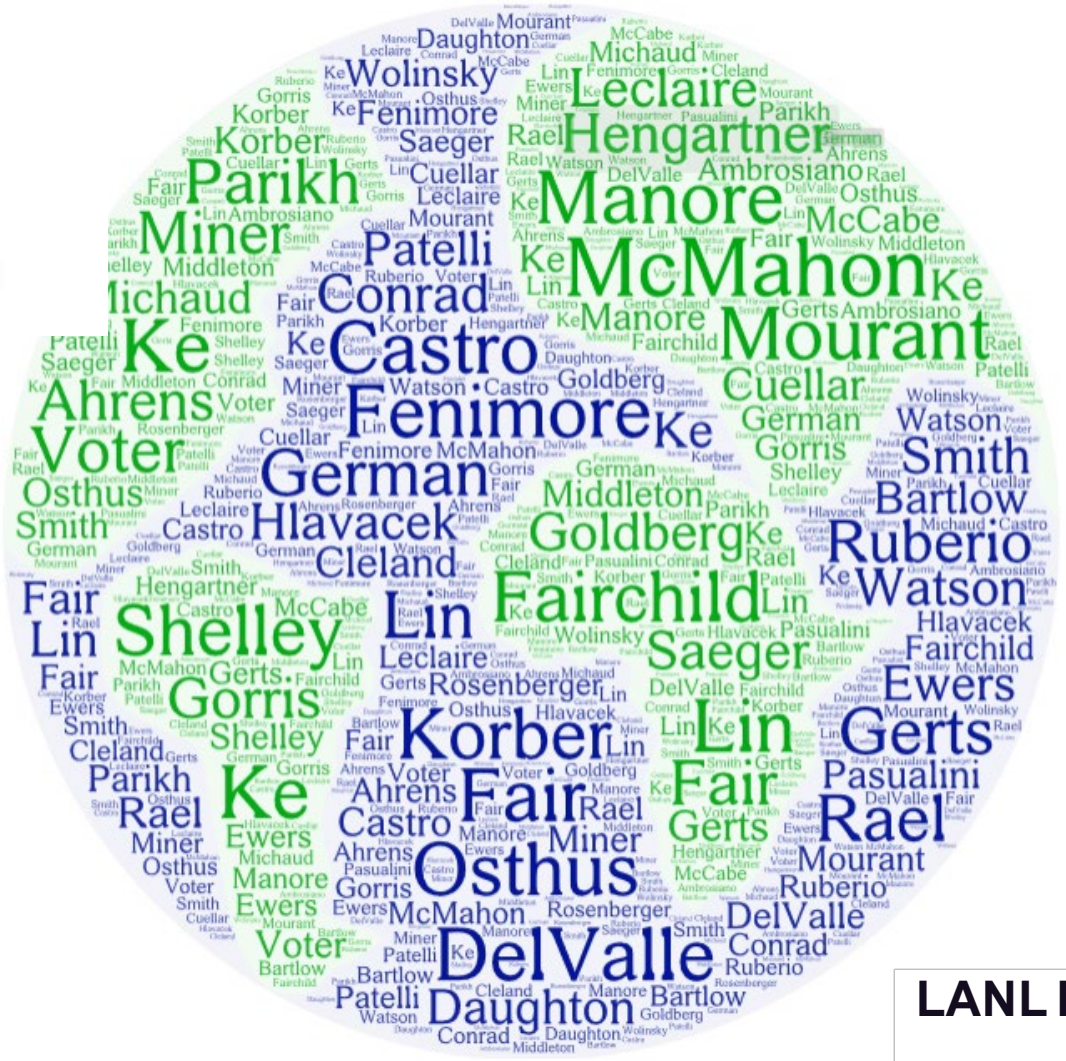


- For deeper courtyards, QUIC dispersal calculations suggest weaker ventilation, leading to airborne concentrations that are similar to those found in fast-food indoor restaurants.

Conclusions

- We do not know everything, but leveraging international networks and community tools will tell us what needs to be done to beat this outbreak.
- Decision makers need facts supported by science and data.
- A layered approach is the best approach.
- LANL has used multiple models to study the impacts of different planning assumptions and interventions (e.g., reopening, physical distancing, vaccination, virus properties, supply chain, hospitalizations) as well as to understand the biology and movement of the virus.
- We need to maintain capabilities for the next disease outbreak.





LANL Modeling Teams!